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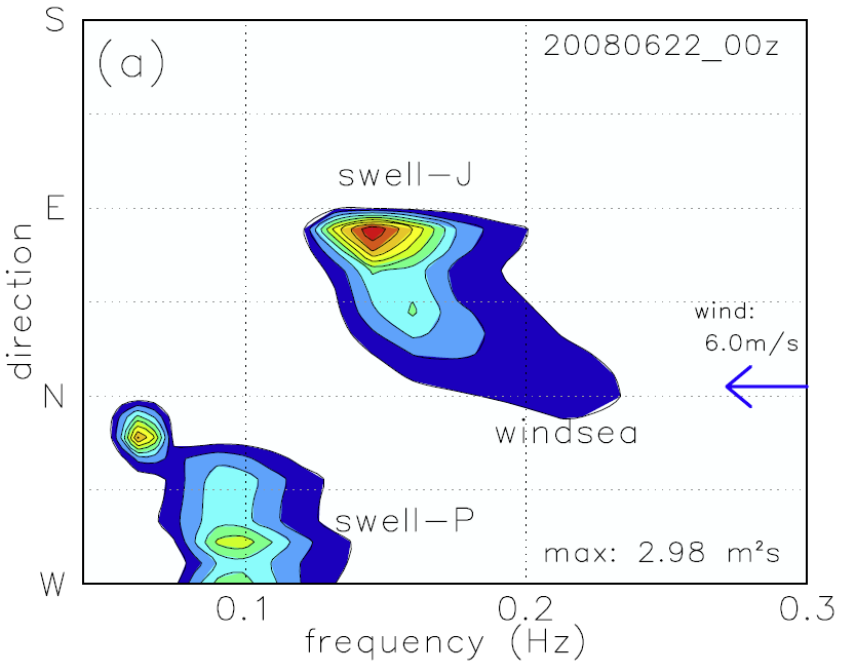
Freak Wave in Two Wave Systems

Nobuhito Mori
Kyoto University, JP

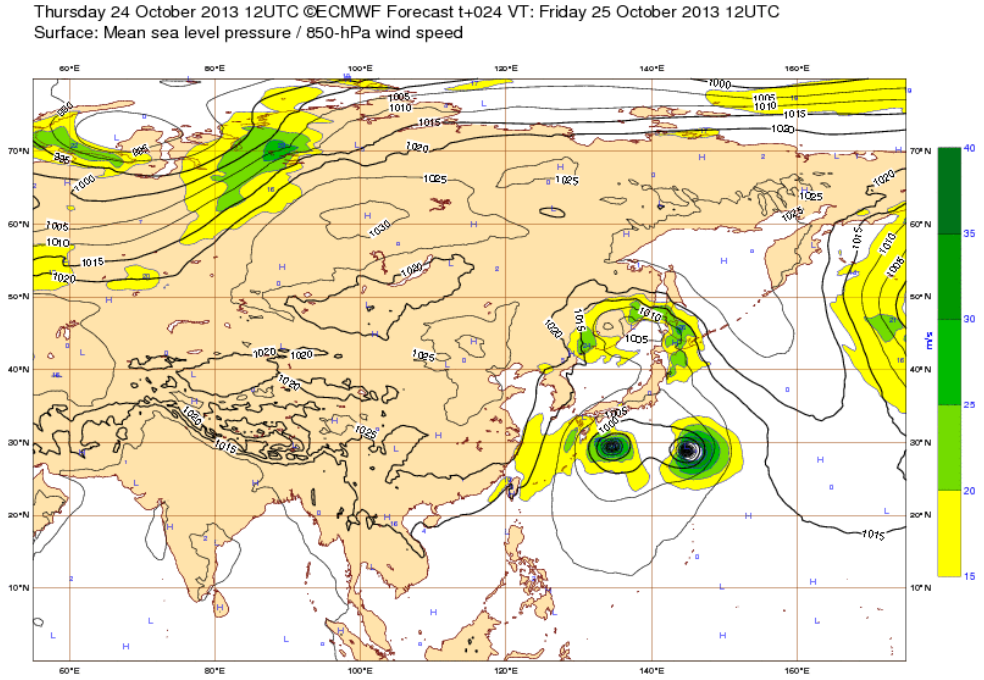
Suzana Ilic and Jamie Luxmoore
Lancaster University, UK

Collaborators
Peter McClintock, Victor Efimov, Aneta Stefanovska, Juana Fortes, Joao Santos, Rui Capitao, German Kolmakov, Csaba Pakodzi, Carl Trygve Stansberg, Ivar Nygaard

Background



Tamura et al.(2009) Ship accident and two systems



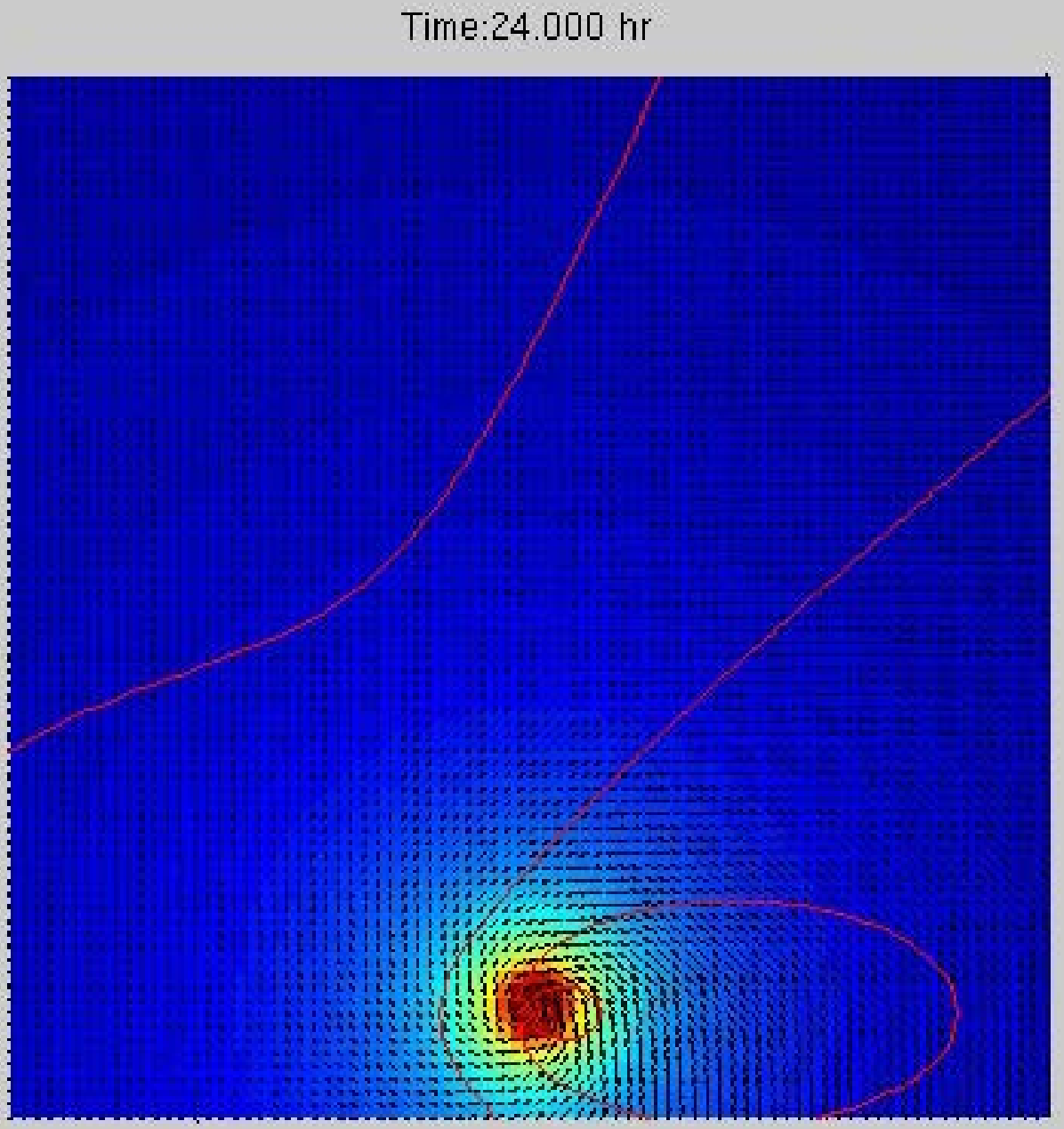
Can we estimate Hmax from the spectra for bimodal system?

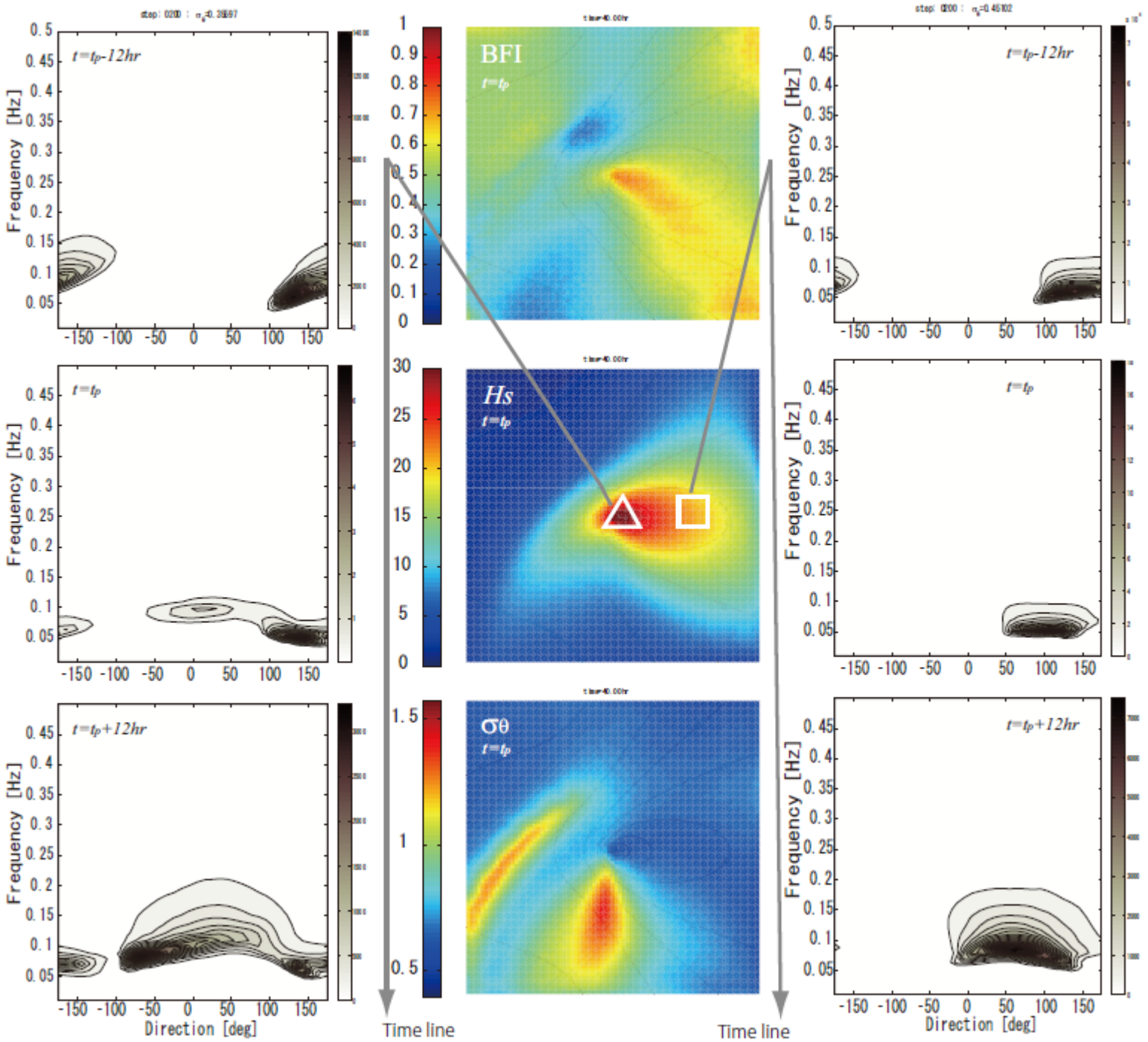
Target and Methodology

1. Target
   - Estimation of maximum wave height in the bimodal system.
   - Directional spectrum evolution
2. Methodology
   - Wave tank experiments
   - Spectral wave modeling
   - Discussion

Summary

- Sensitivity of wave angle to wave statistics in bimodal system was examined.
- The wave height statistics mainly follow linear short-term wave theory, if two wave systems have same energy.
- The nonlinear transfer is less significant for the evolution of spectra in the bimodal sea states.
- The further discussion is required for bimodal sea states have different energy.


Time:24.000 hr



P_{min}=960hPa
r_0=50km
V=50km/h

Mori et al. (2011) JGR

Previous Studies

- Experiments
  - Extreme wave height: Petrova and Guedes-Soares(2009, 2o11)
  - Crest and trough amplitude: Petrova et al. (2013)
- Numerical modeling
  - Deep-water: NLS:Toffoli (2011)
  - Intermediate water-depth: Kundu et al. (2013)
- Third order nonlinear interactions
  - strong nonlinear interactions can be possible depend on angle and frequency ratio: Masson (1993)

Maximum kurtosis vs angle
Bimodal case

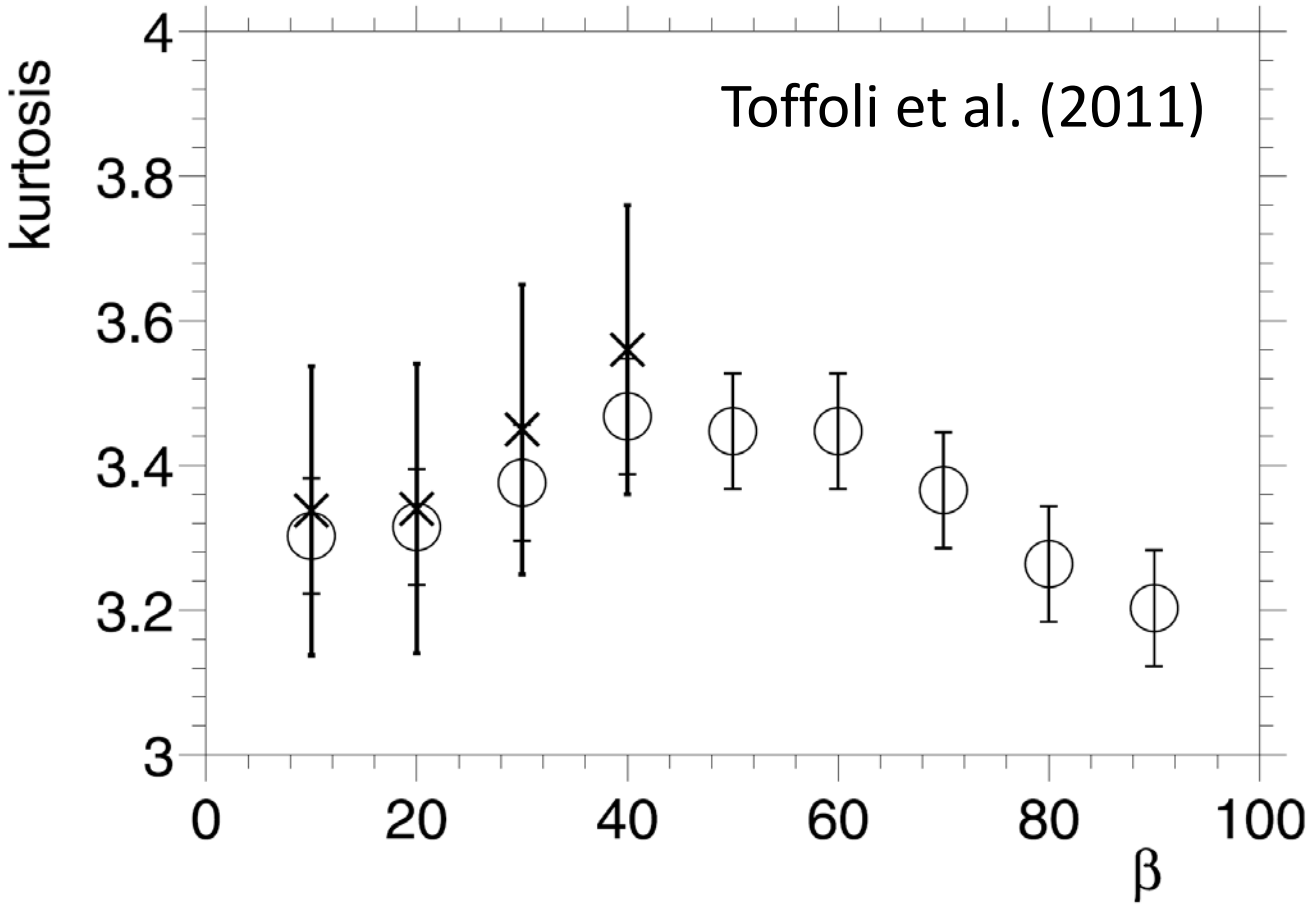


Figure 3. Maximum recorded kurtosis as a function of β: laboratory experiments (crosses); numerical simulations (circles).

System of Freak Wave Prediction

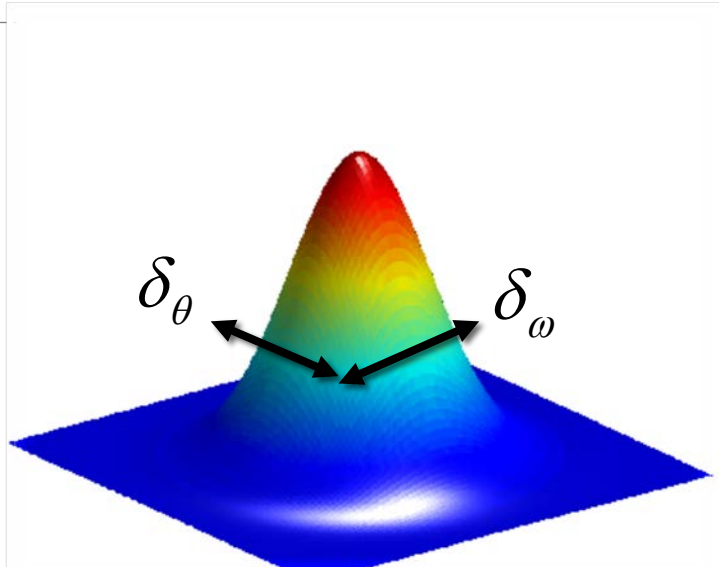
e.g. Wased et al. (2009), Mori et al. (2006, 2011)

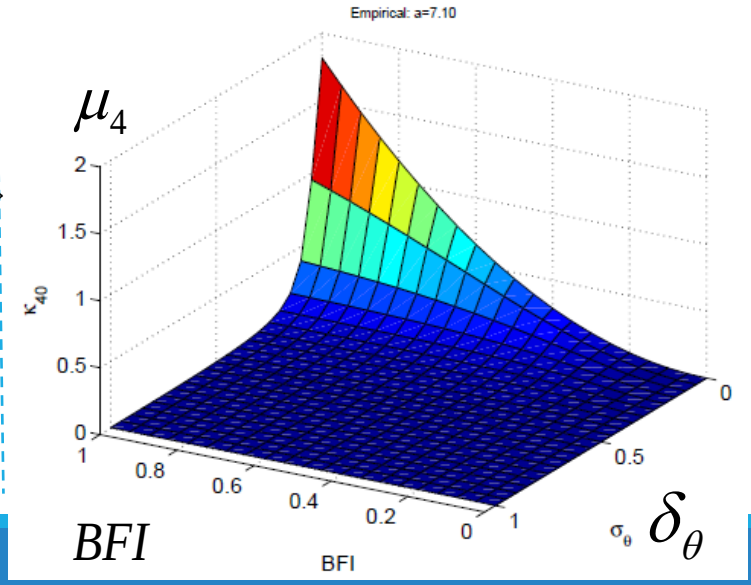
1. $$BFI \propto \frac{ak}{\delta_\omega}\left(1-\frac{\delta_\theta^2}{2\delta_\omega^2}\right)$$

2. $$\mu_4 \propto BFI^2$$

3. $$p(H_m)=\frac{N}{4}H_m e^{-H_m^2/8}\left[1+(\mu_4-3)A(H_m)\right] \times \exp\left\{-NH_m e^{-H_m^2/8}\left[1+(\mu_4-3)B(H_m)\right]\right\}$$

4. $$P_{freak}=1-\exp\left\{-e^{-8}N\left[1+8(\mu_4-3)\right]\right\}$$





Experimental Setup

- General conditions
  - MARINTEK ocean basin
  - 24 wave gauges
  - JONSWAP spectra
  - Deep-water condition
  - 20 mins = 1000 waves
- Wave system 1
  - Hs = 5.8 cm
  - Tp = 1.0 s
  - γ=3
  - N=50
- Wave system 2
  - Hs = 5.8 cm
  - Tp = 1.0, 1.1, 1.25 s
  - γ=6
  - N=100

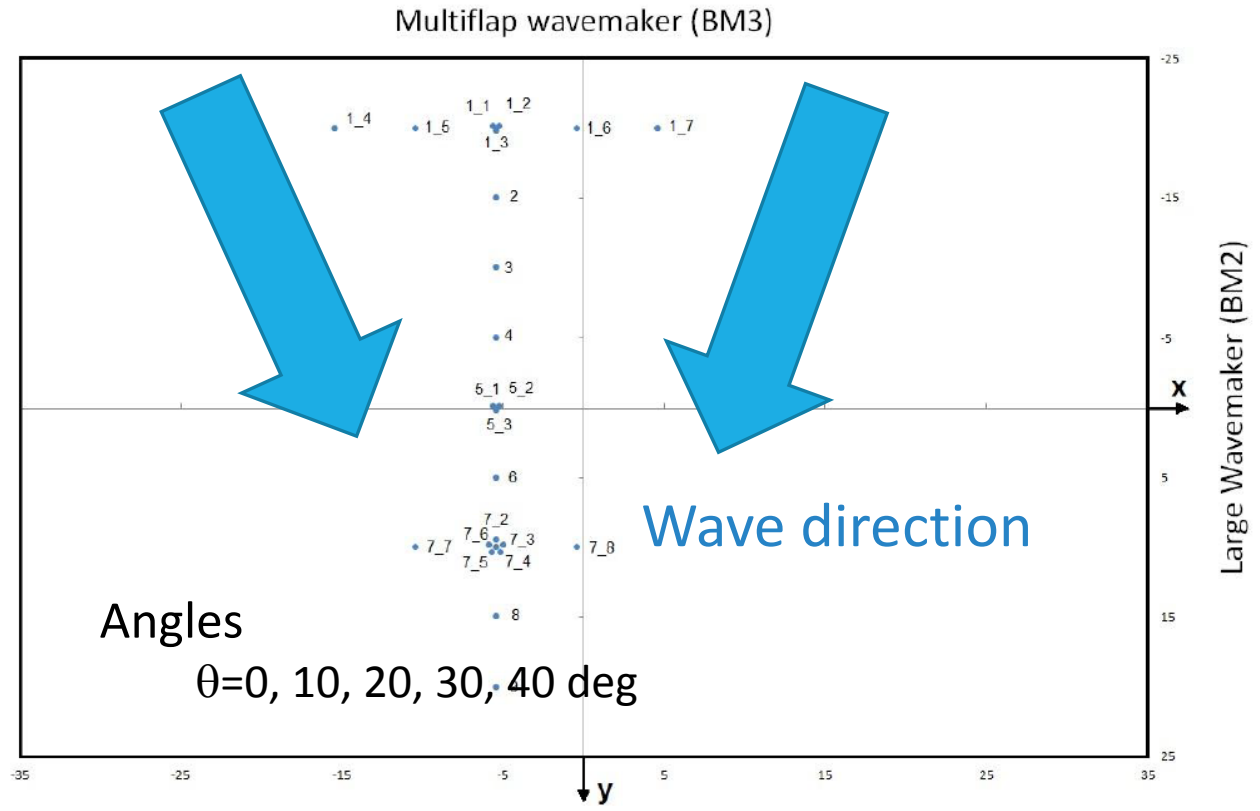
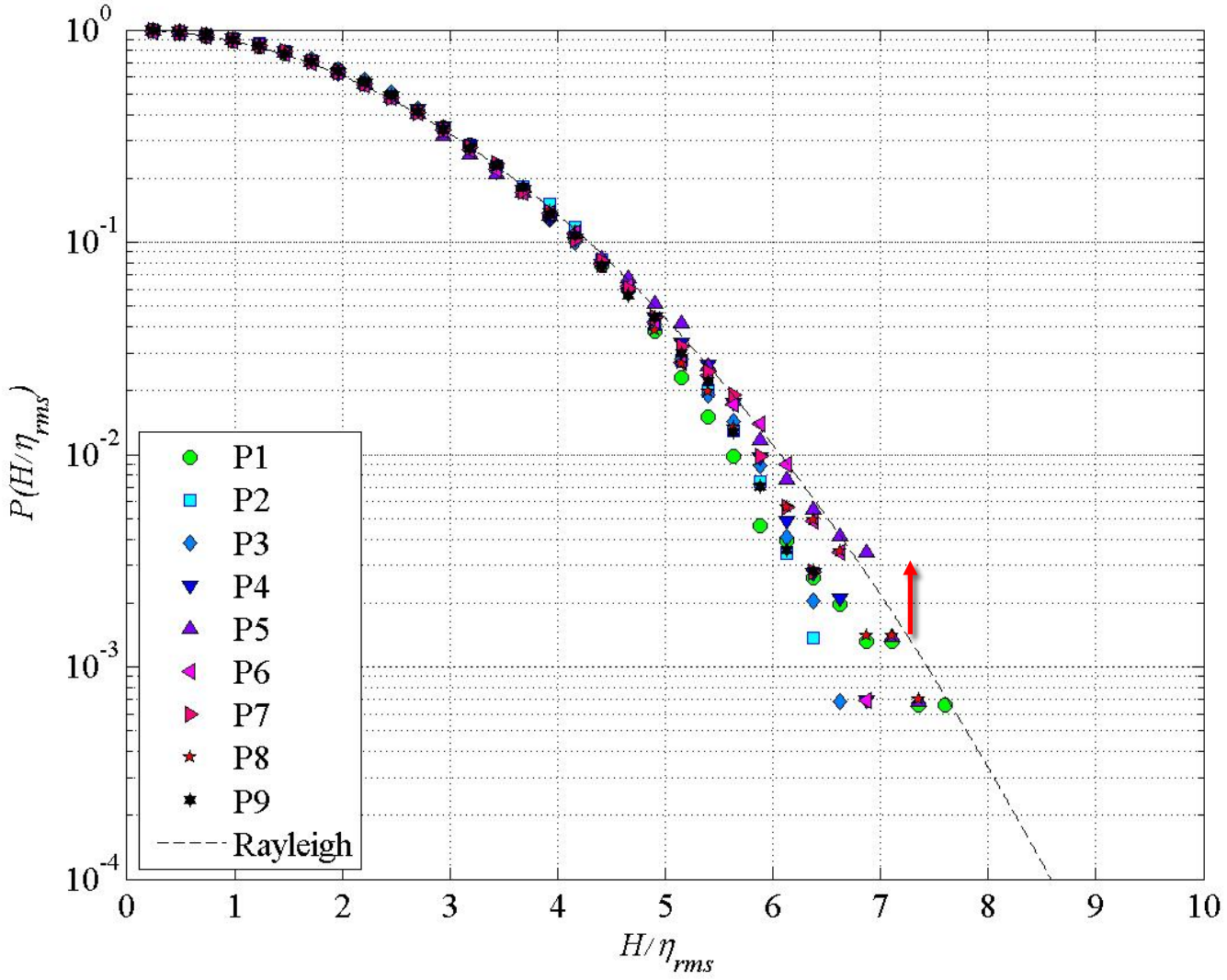
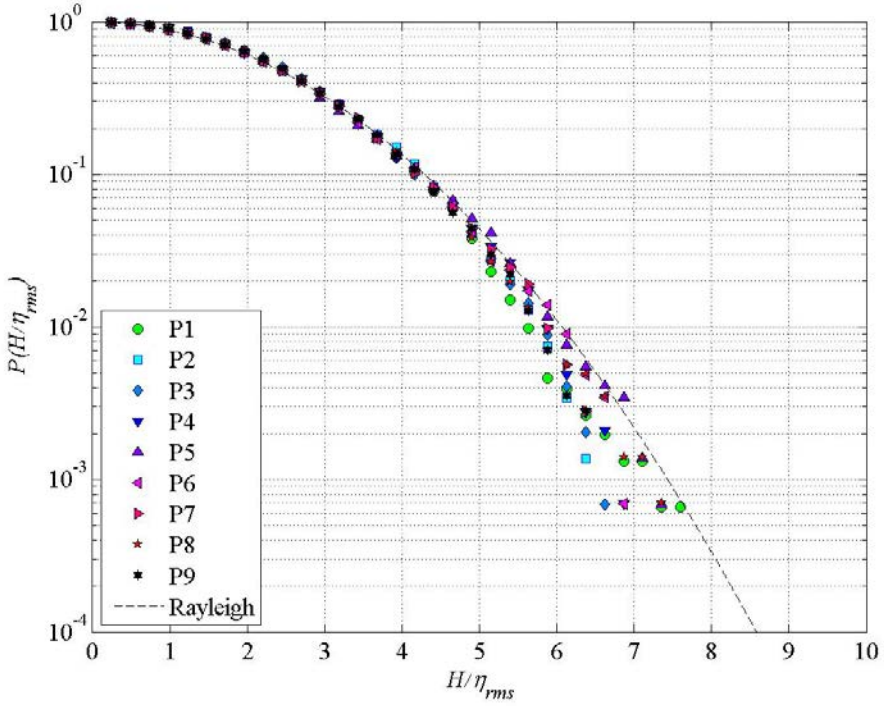


Figure 2.1: General view of the wave gauges and wavemakers in the Ocean Basin

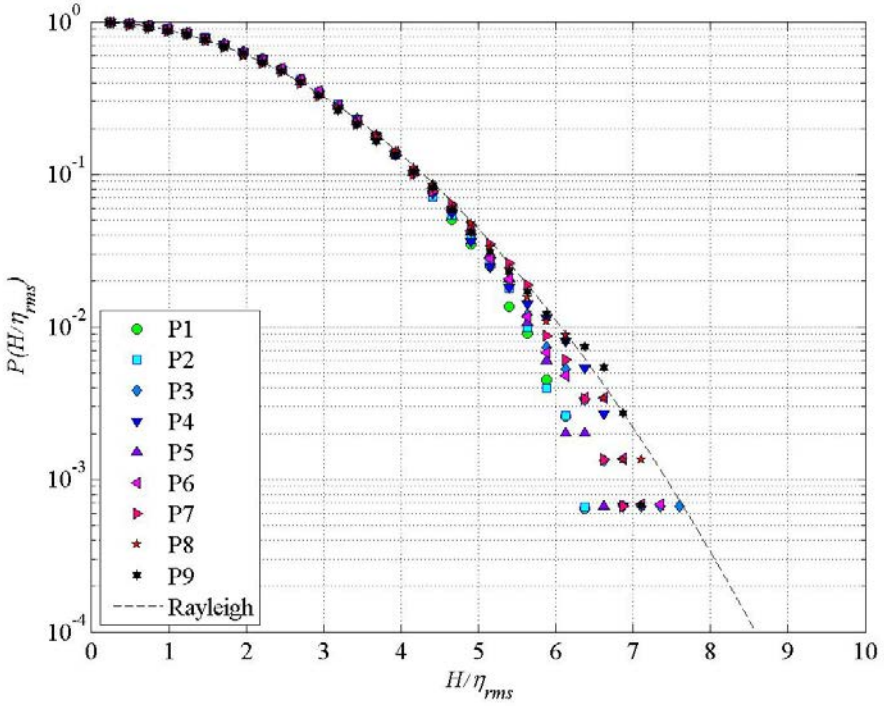
Exceedance probability of wave height Unidirectional case



Exceedance probability of wave height Bimodal case

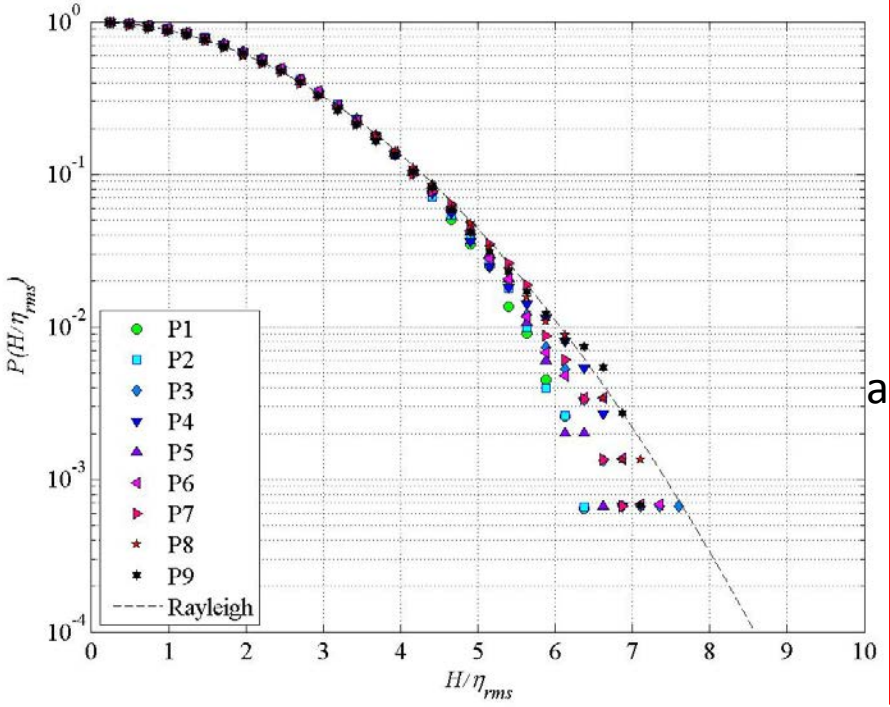


θ=0



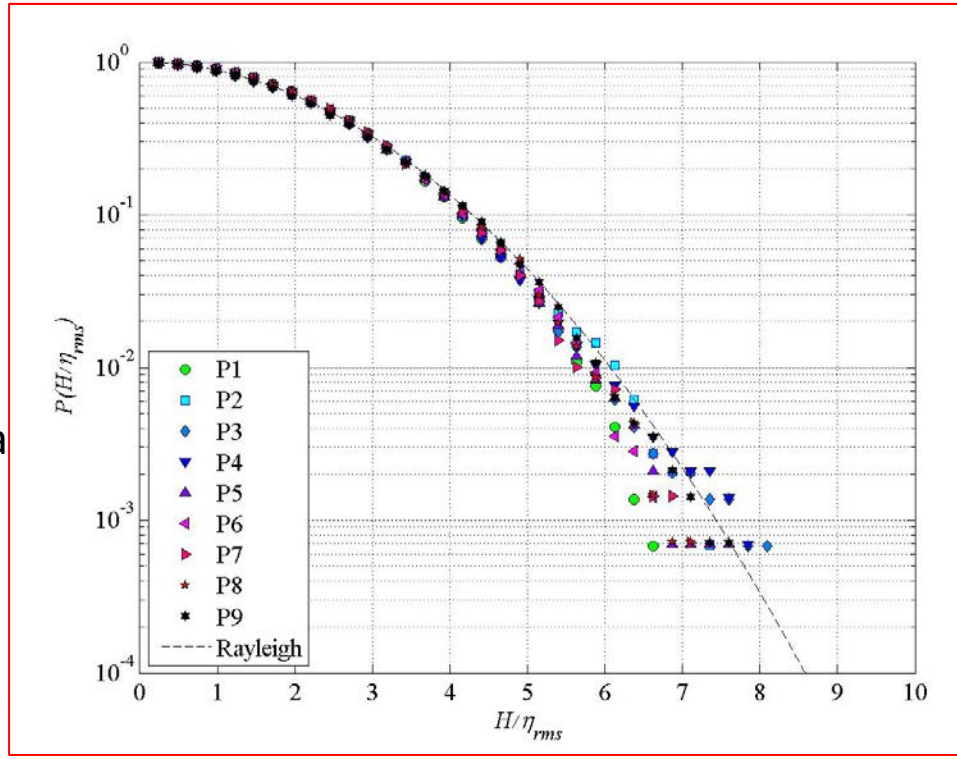
θ=40

Exceedance probability of wave height



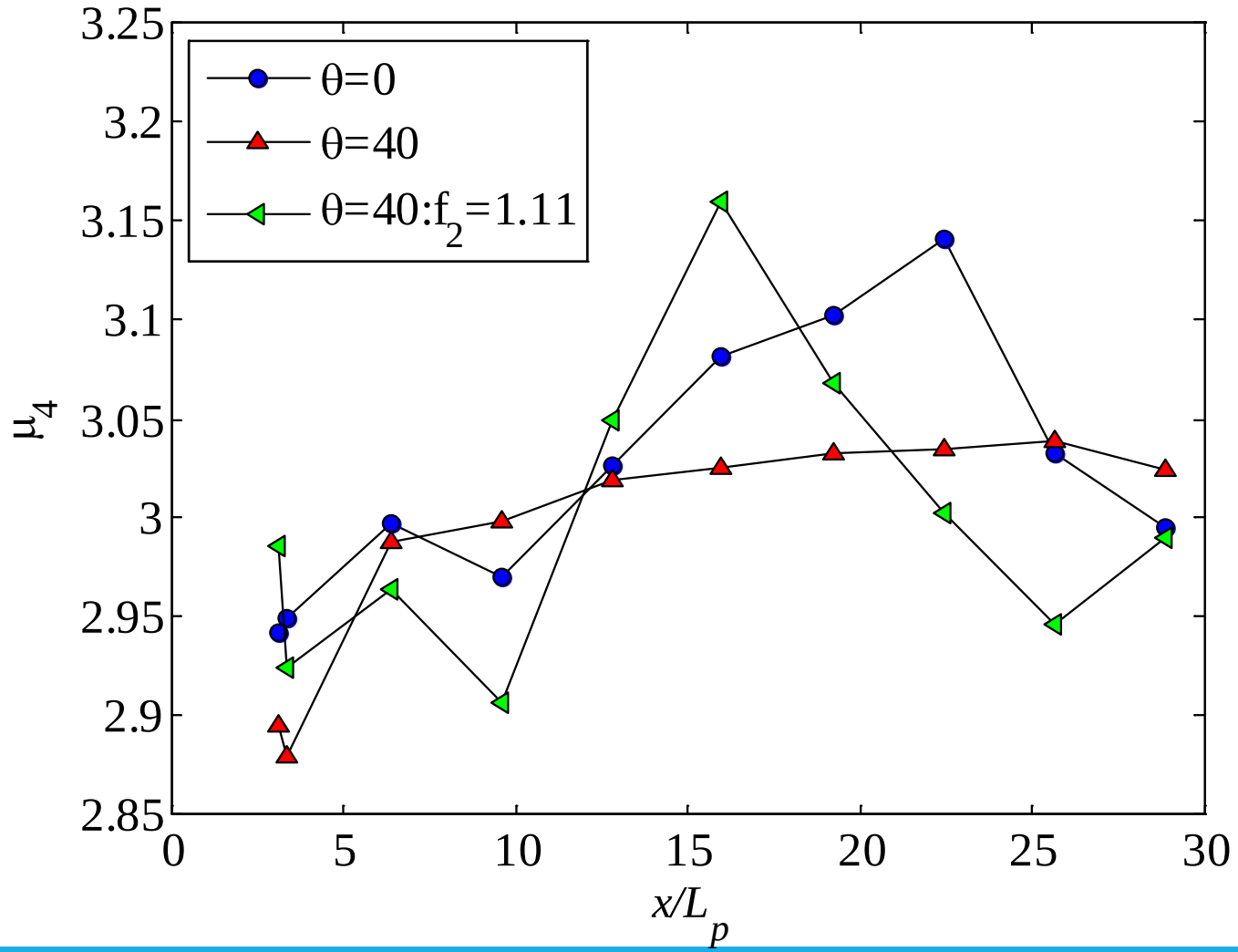
θ=40
f_1/f_2=1.0

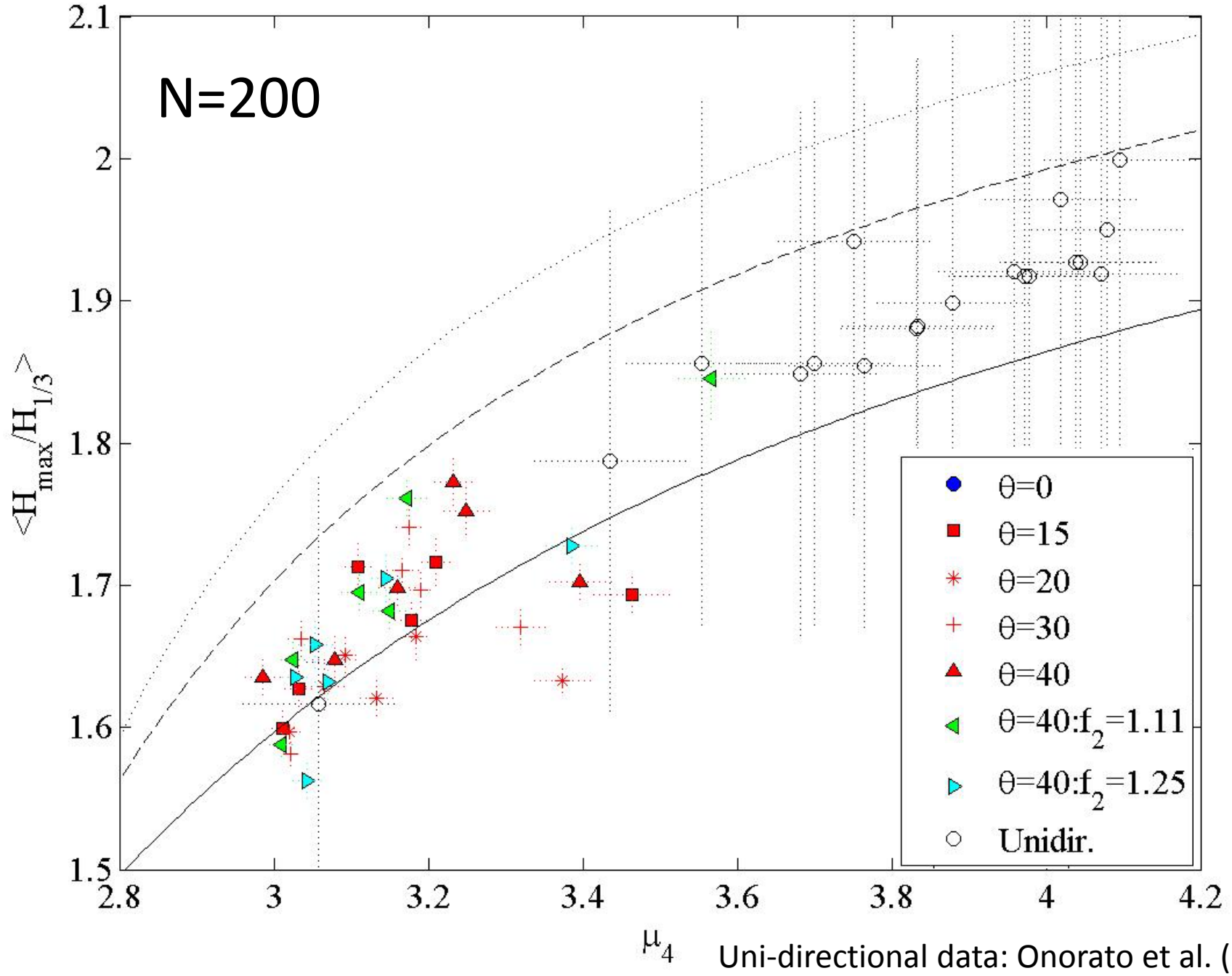
a



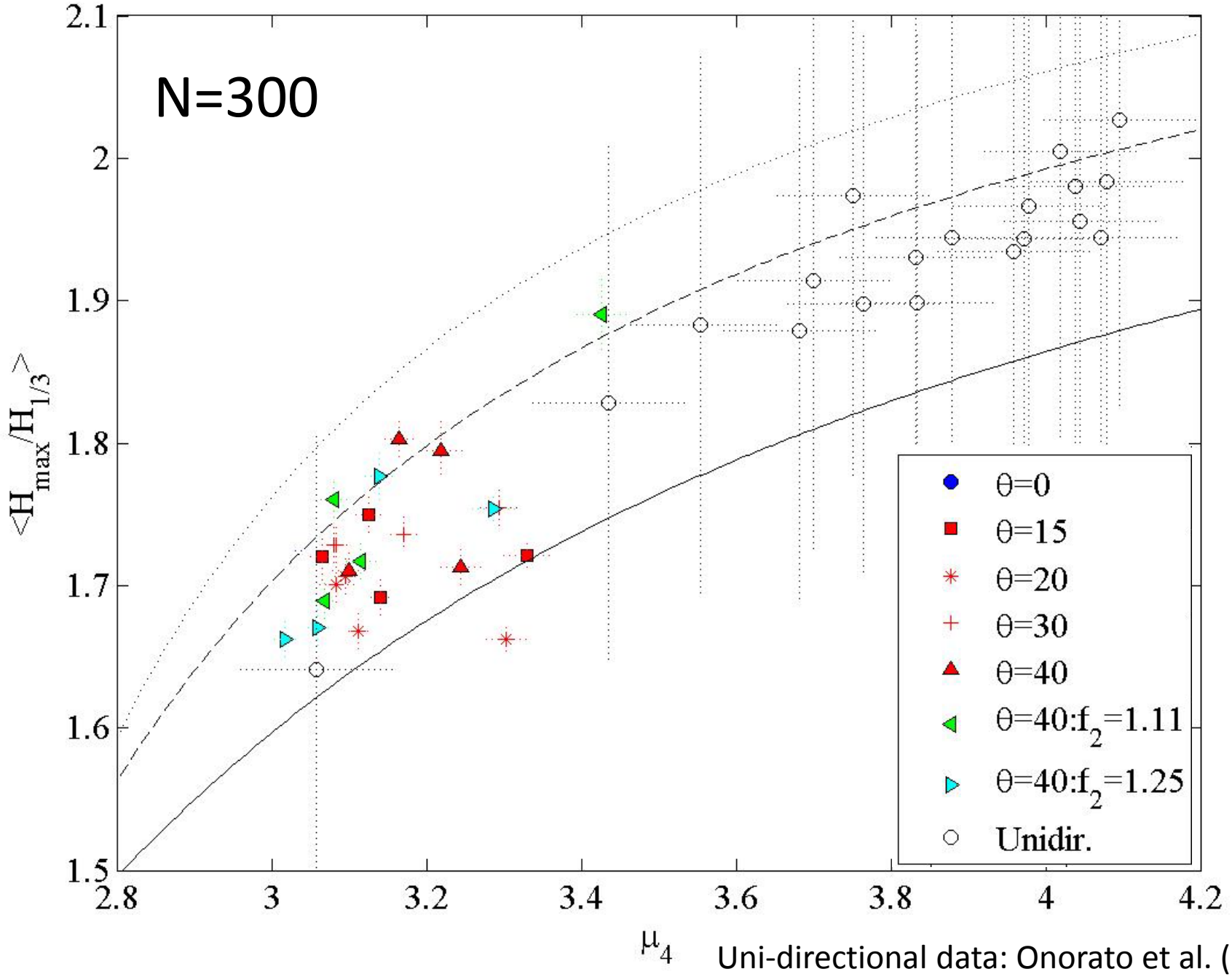
θ=40
f_1/f_2=1.11

Evolution of kurtosis μ_4





Uni-directional data: Onorato et al. (2007)



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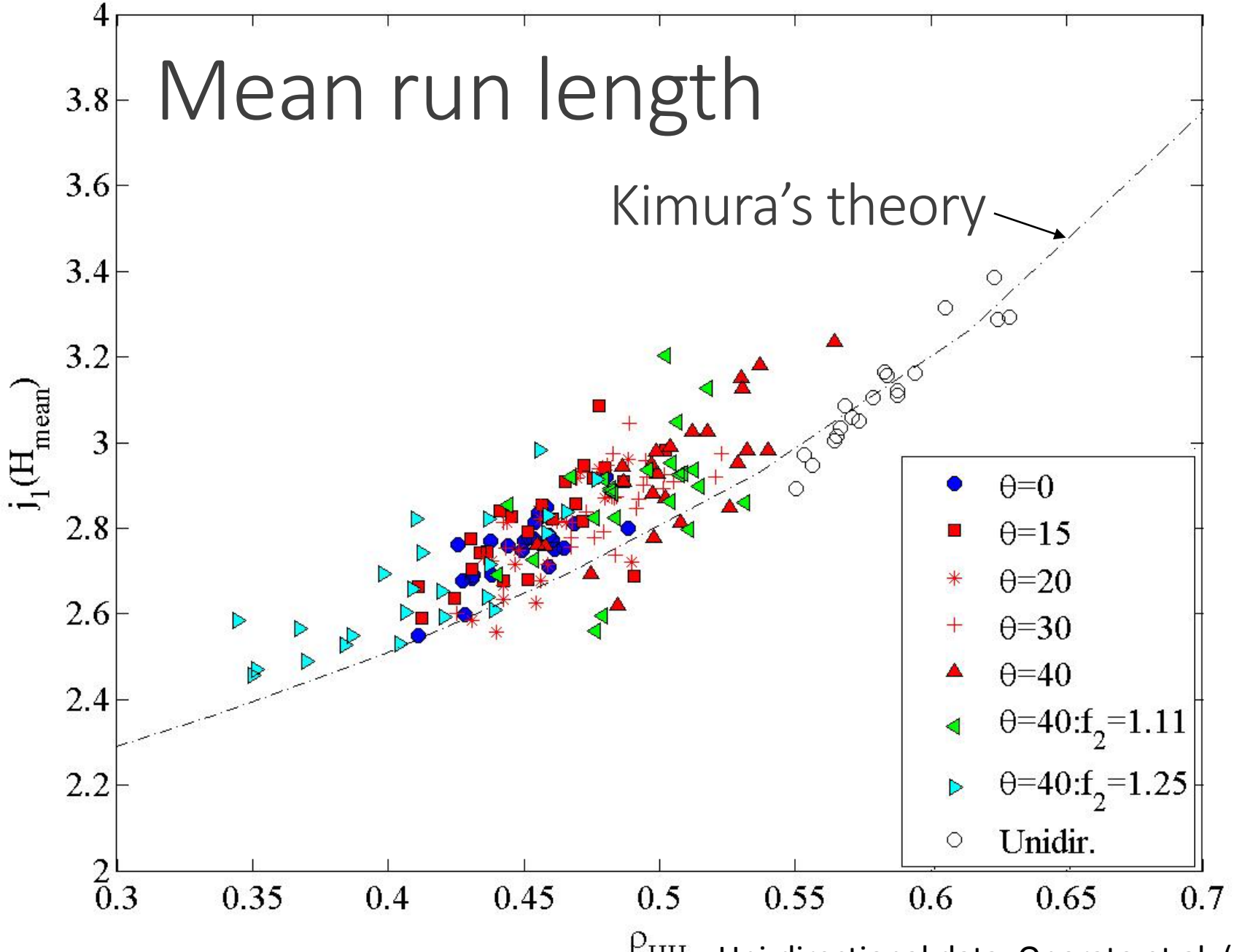
Mean run length



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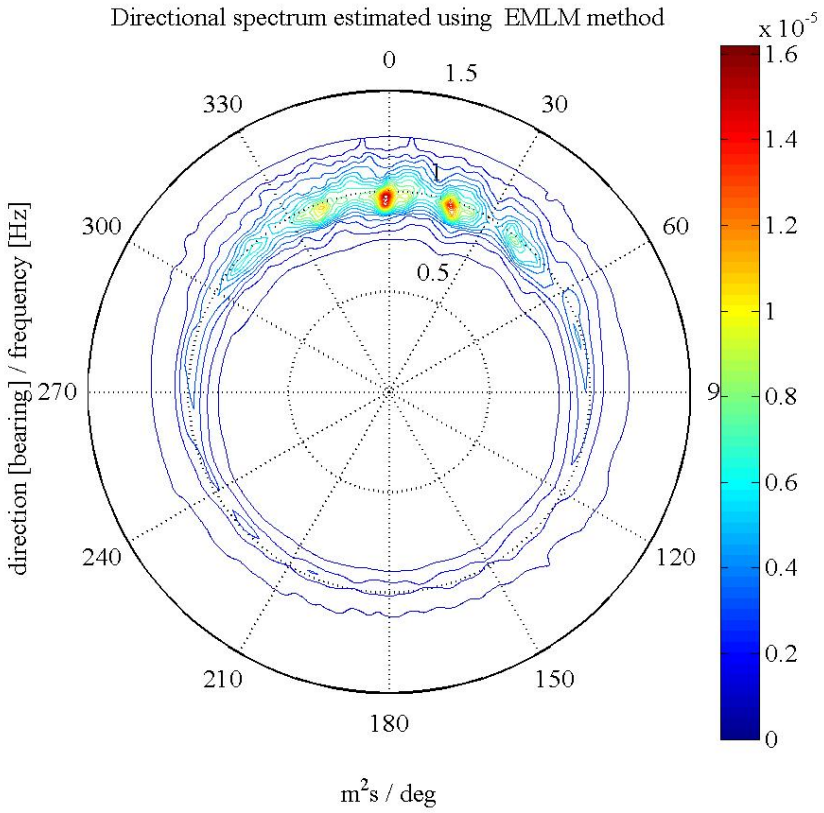
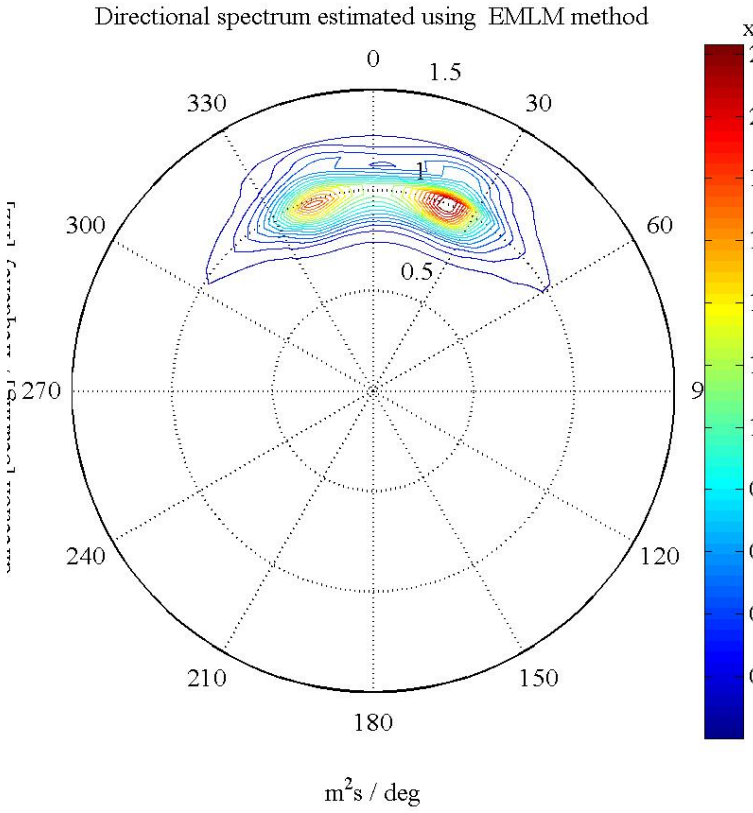
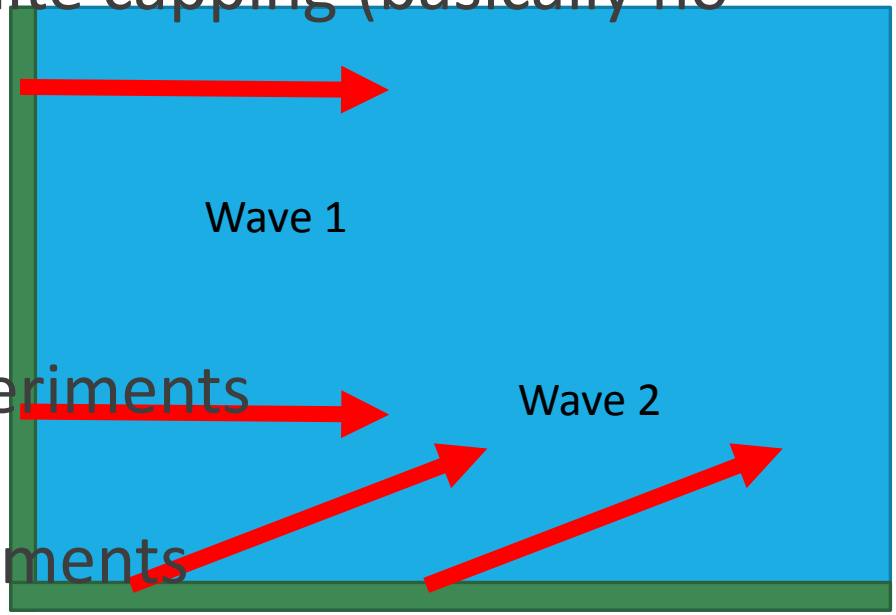




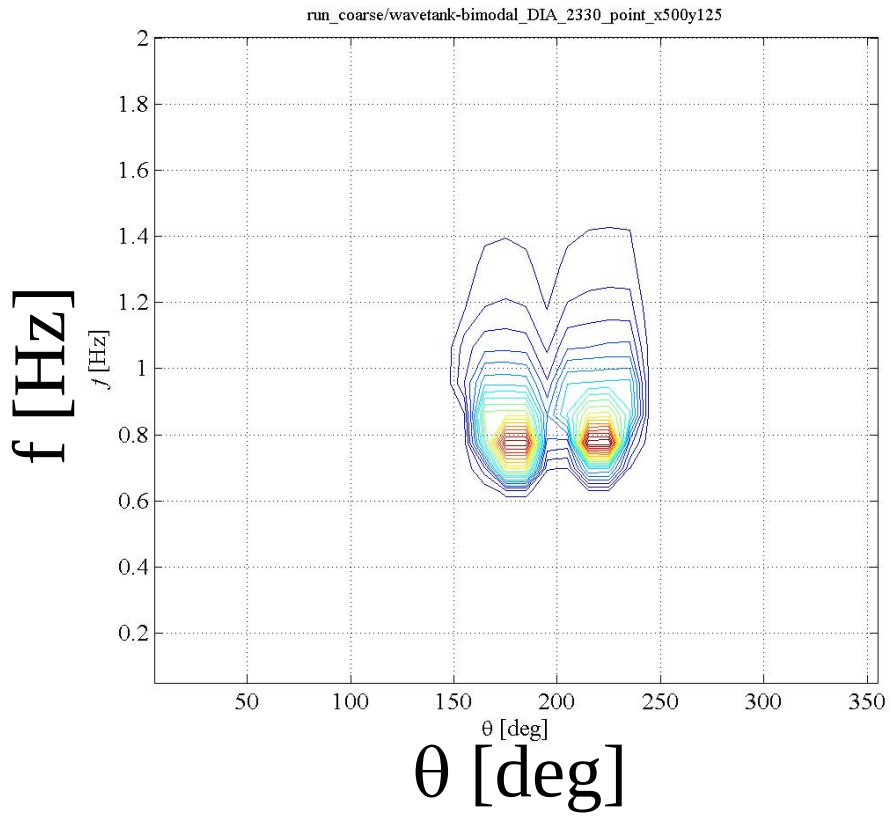
Case 2330: angle=40 deg., T1/T2=1.0s/1.0s

Numerical setup

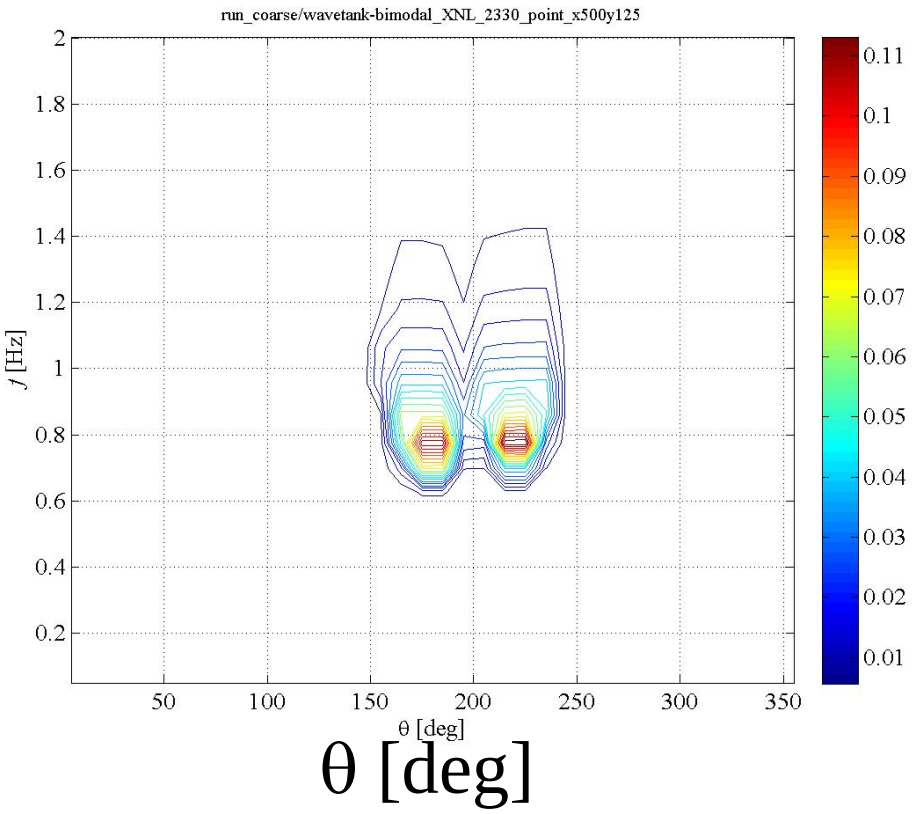
- Delft SWAN version 40.91
- Physics
  - Nonlinear interactions: DIA and Exact solution
  - Energy dissipation: white capping (basically no dissipation)
  - No wind
- Incident waves
  - Hs: matched with experiments
    - 8.0 cm
  - Tp: same to the experiments
    - 1.0, 1.11, 1.25
  - Directional spreading



Shape of Directional Spectra case 2330 (40degree)



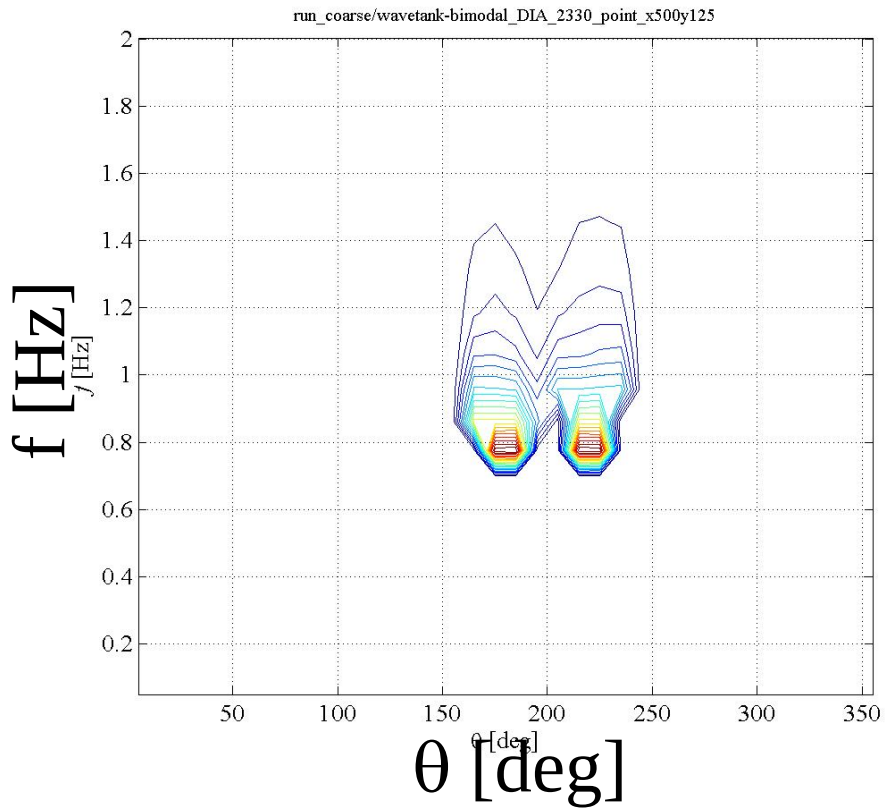
DIA



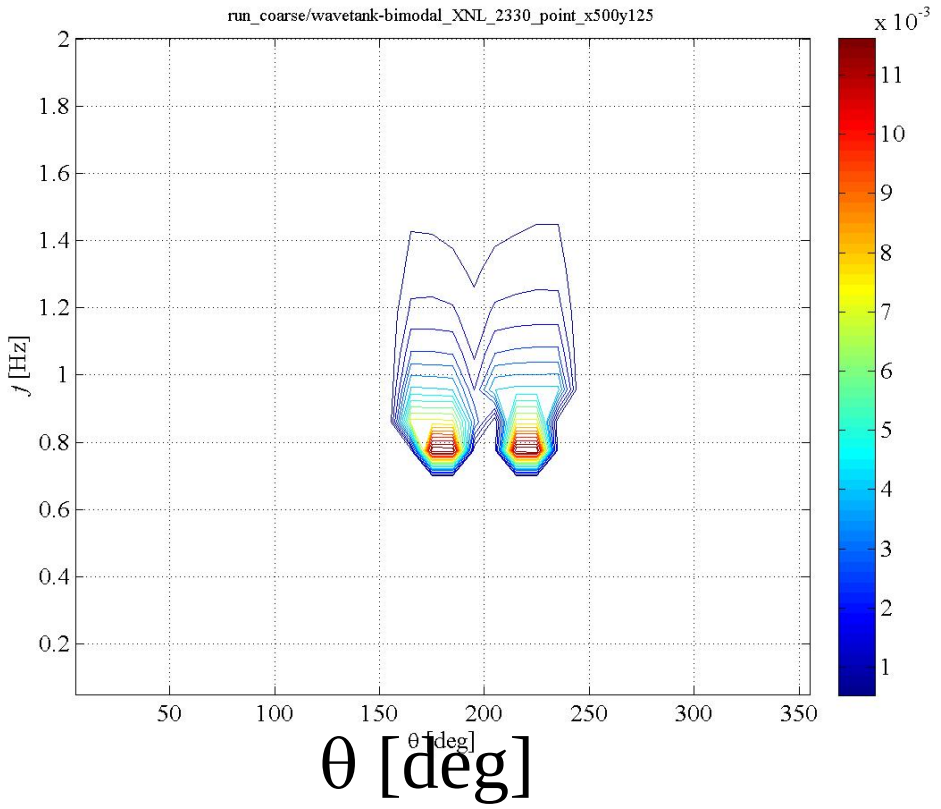
Exact

Shapes of spectra are not so different

Shape of Energy Transfer case 2330 (40degree)

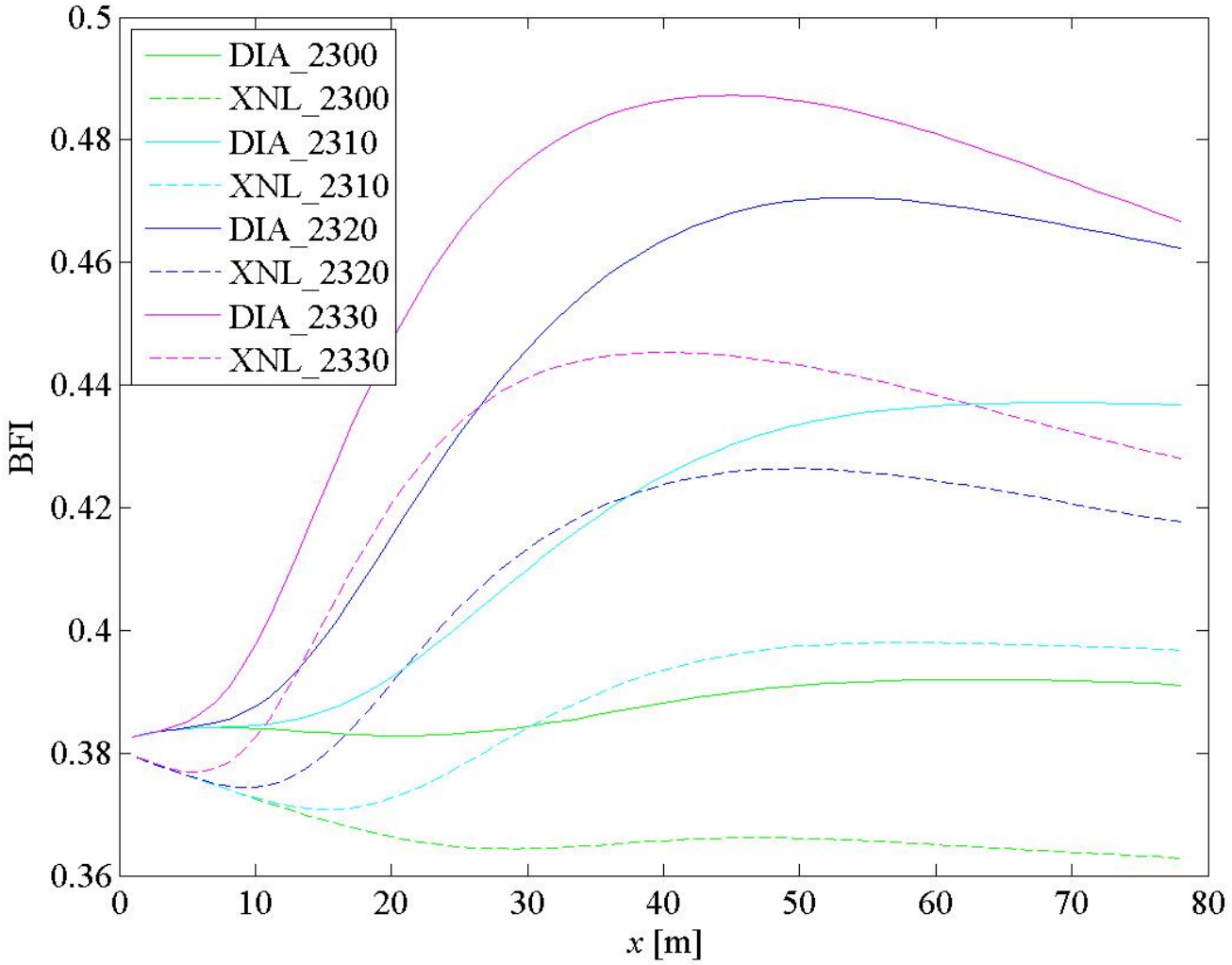


DIA



Exact

Spatial evolution



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- The wave height statistics mainly follow linear short-term wave theory, If two wave systems have same energy.
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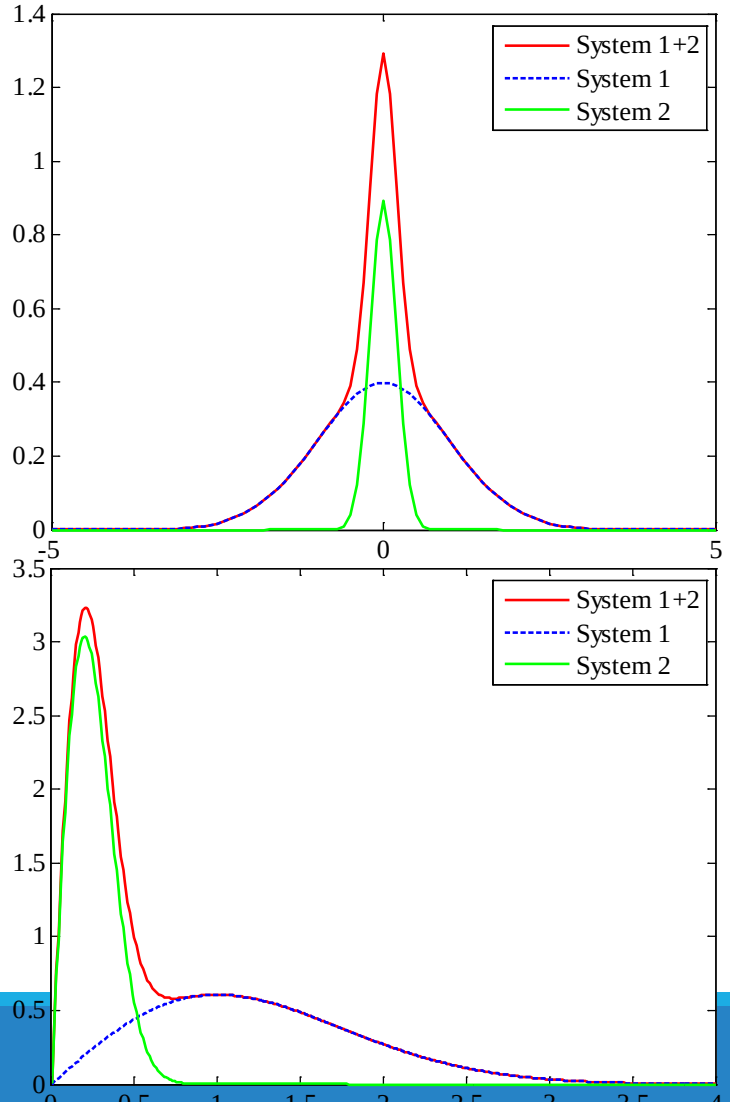
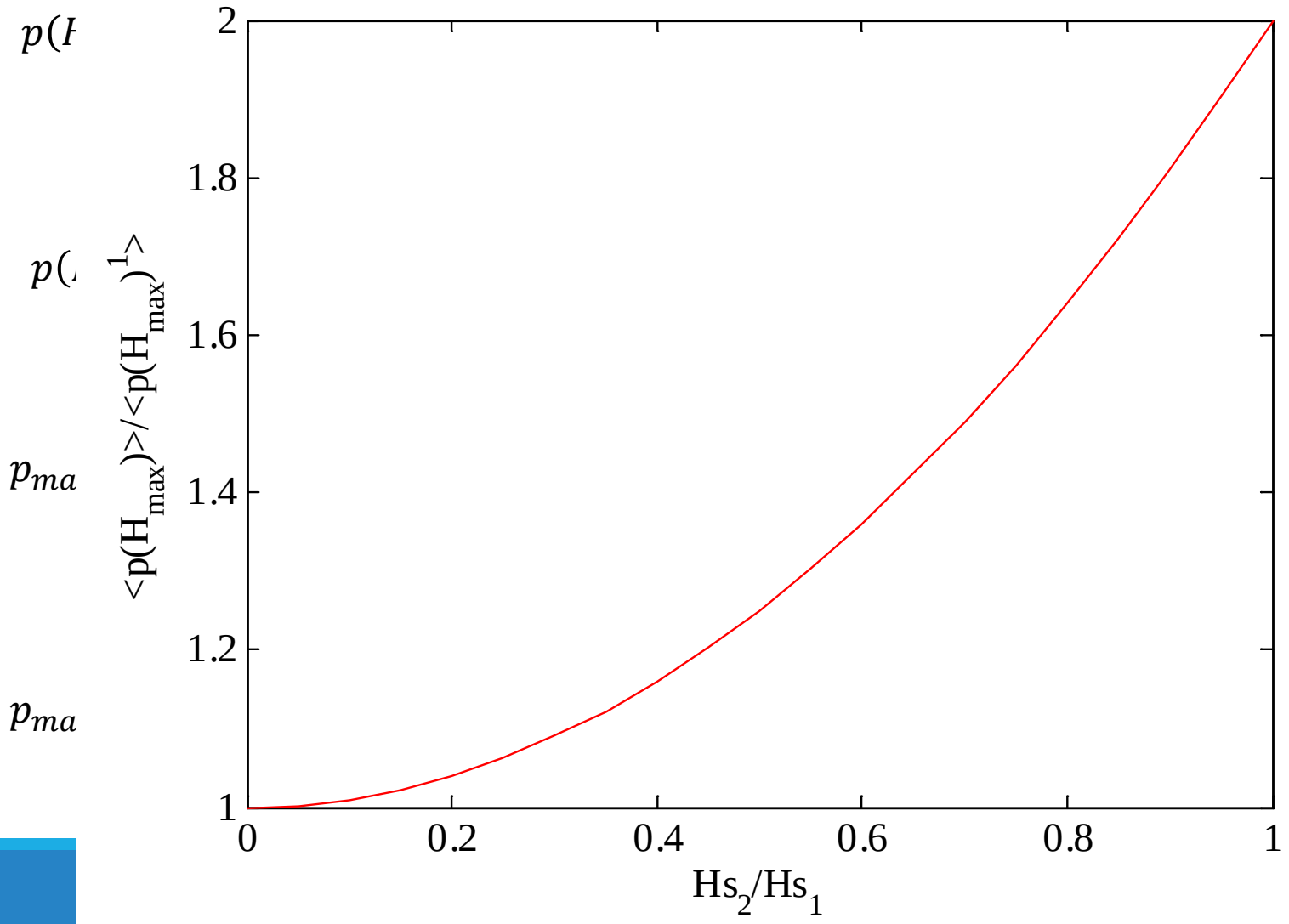
Further Discussion



- How can we measure the deviation due to nonlinearity for two-systems?
- Can we use the classic short-term wave statistics for bimodal sea states?

Extension of short-term wave statistical theory to two systems



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